Empirical Evidence on the Effectiveness of Environmental Taxes

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Abstract:
The aim of this study is to determine whether environmental taxes affect levels of pollution and energy consumption. Using a panel of EU members and Norway, we find a significant negative relationship between taxes and pollution, but no relationship with energy consumption. A further contribution to the literature involves the use of the Arellano-Bover approach to dynamic panels, to account for the potential partial adjustment towards desired or target levels of pollution and energy usage. The results provide evidence of partial adjustment, as well as evidence of the negative relationship between environmental taxes and pollution.

Key Words: Environmental tax, pollution, energy, dynamic panel, partial adjustment.

J.E.L.: Q32, Q43, E62

1. Introduction

As a result of recent concerns relating to the harmful effects of global warming, policy makers have become increasingly interested in the use of environmental taxation as a means of combating the problem. This research aims to address this issue, by determining whether environmental taxes have had any significant effect on the levels of air pollution and the complimentary phenomenon of energy consumption within the European Union (EU). Over the recent past, the EU members have been set voluntary targets for the reduction in pollution and consumption of hydro-carbon fuels, which have facilitated the sometimes controversial use of environmental taxes across the EU, including the countries that have recently joined.

To date the empirical literature on this issue has mainly concentrated on the use of simulation exercises rather than the use econometric modelling, due to the lack of suitable macro-data. This paper attempts to contribute to the debate on the effectiveness of environmental taxes, by using an EU panel data set to determine if there is any link between environmental taxes and air pollution and therefore whether the EU environmental policy to date has been successful. A further contribution to the literature involves the use of a partial adjustment based model in conjunction with a dynamic panel technique, to account for the target or desired nature of the dependent variable in this type of model.

During the 1990s, beginning with the Scandinavian countries, there have been a number of attempts to introduce Environmental Tax Reform (ETR) in EU members. This has involved shifting the burden of taxation away from factors of production to pollution and the users of natural resources, summarised as a move from economic 'goods' to environmental 'bads'[1]. One of the main ways in which EU governments have attempted to do this is through the use of energy taxes, in order to encourage a reduction in carbon emissions. Other options involve direct taxes on resource use and the removal of subsidies, which could be potentially harmful to the environment. However as a contrast to this interpretation of improving the environment, other studies such as Ekins and Speck (1999) have argued that any environmental taxes introduced by the EU have suffered from extensive exemptions by many industries, as a result of fears of uncompetitiveness. This has caused some of the most energy-intensive industries in the EU to be exempted from taxation to prevent reduction in international competitiveness, which could undermine the effectiveness of these taxes.

The main empirical work on environmental taxation has centred on the use of simulations on the impact of ETR on the environment, use of natural resources and the wider economy. Most of the studies conclude that increased environmental tax and ETR can have beneficial effects on the environment. (see Baranzini *et al.* (2000) and Bosquet (2000)). In addition there has recently been a substantial level of research into determinants of pollution and energy usage. Grossman and Krueger (1995) provided evidence for a non-linear relationship between per capita income and pollution, termed the 'Environmental Kuznets Curve', with an inverted U-shaped

[1] The approach to environmental taxation in the EU has concentrated on the use of taxes to improve the environment, whilst using the revenue raised to reduce the distortionary taxation on labour and production. This policy is often regarded as producing a double dividend whereby the environment is improved and at the same time the economy benefits through the reduction in these distortionary taxes (Bosquet (2000)). However a number of studies such as Goulder (1995) and Goulder (1996) suggest any benefits of the double dividend may be limited and depend on the levels of pre-existing taxes.

relationship, which has also been found in other studies (e.g. Antweiler *et al*. (2001) and Roca and Serrano (2007)). However other studies such as Stern and Common (2001) suggest the relationship could be monotonic, when using alternative approaches. Additional studies such as Antweiler *et al*. (2001) and Cole and Elliot (2004) suggest capital and investment in various forms are important determinants. Other studies have emphasised the inclusion of political variables, such as Neumayer (2003), as well as trade related variables as in Jaffe *et al.* (1995) although their effect on pollution is at best ambiguous. However as yet there is little evidence of fiscal factors being considered in this area of the empirical literature at the macroeconomic level[2].

Following the introduction, the methodology used in this study is outlined and the form that ETR has taken in the EU member states discussed. The data and results are then examined and finally we suggest some conclusions and policy implications of the study.

2. Methodology

2.1 Modelling pollution and energy consumption

The model of the determinants of both pollution and energy consumption used in this study are partially based on the conventional approach suggested by Grossman and

[2] A related strand of the literature examines the effect of environmental taxes at the micro level, these studies use both simulation and econometric based approaches and in general find that using firm level data, the use of environmental taxes to reduce pollution has had at best mixed results (Millock and Lauges, 2006). In a similar micro-based approach Brannlund *et al*. (2007) assess the use of energy based taxes on energy consumption.

Krueger (1995) and Cole and Elliot (2003) among others in which per capita GDP measures are used as determinants of pollution. Per capita capital formation is also included in the model, to proxy the ratio between capital and labour supply, as measures of capital and investment have proven to be important determinants in other models. The final determinant is the environmental tax imposed in each country included in this study. This produces the following relationship:

$$pcpoll_{it} = \alpha_0 + \alpha_1 pcy_{it} + \alpha_2 pcy_{it}^2 + \alpha_3 pck_{it} + \alpha_4 tax_{it} + u_{it} \qquad (1)$$

Where $pcpoll_{it}$ is per capita pollution (total greenhouse gas emissions) in the first model and per capita energy consumption (tonnes of oil equivalent) in the second complimentary model. Total emissions are used rather than individual pollutants in this study, as this is the measure the members are required to target in the EU. pcy_{it} is per capita real GDP, pcy_{it}^2 is per capita real GDP squared, pck_{it} is the per capita capital formation and tax_{it} is environmental taxes expressed as a proportion of both GDP and total tax revenue (All variables in logarithms, except taxes which are expressed as a percentage).

It is often assumed in the empirical literature that per capita income will have a non-linear relationship with pollution, as originally observed by Grossman and Krueger (1995), so a squared per capita GDP measure is also included in the model. They incorporated this variable to account for the inverted U-shaped relationship, whilst also including a cubic version of this variable. The approach adopted here follows other studies, such as Stern and Common (2001) in including both a linear and non-linear form of per capita GDP. Other studies have also incorporated lagged values of per capita GDP, but as these are used as instruments in the dynamic panel model, they have not been included in this specification. The per capita capital variable should have a negative relationship, as increasing investment should facilitate the move to more advanced energy efficient production techniques. The environmental taxes should have a negative effect, assuming the exemptions have not significantly reduced their effectiveness, as either they encourage more efficient use of resources or a reduction in energy consumption.

In this study the environmental tax revenue as a proportion of GDP and total tax revenue is used as a proxy for the tax rate. The measure of environmental tax revenue is based on the internationally recognised definition used by the Statistical Office of the European Union (Eurostat) and accepted by the main international bodies, such as the Organisation for Economic Co-operation and Development (OECD). An environmental tax is defined as any tax, which has a physical unit as a base and for which there is evidence that it has a specific effect on the environment[3].

The data on environmental tax revenue is predominantly comprised of taxes on energy products, such as the duty charged on hydrocarbons in the transport sector, as well as the industrial sector. It also includes the fossil fuel levy, which is a tax on electricity generated using fossil fuels. A recently introduced tax is the climate change levy, including petroleum, gas, coal and electricity. Further related tax sources include

[3] As recognised in other studies, there is some debate over what counts as a tax, in particular the use of earmarked sources of revenue, as discussed in Newbery and Santos (1999). For the benefit of this study we rely on the definitions used by Eurostat, which is common across all the countries in the study. As noted earlier this is a macro based study using aggregated data for both taxes, pollution and energy consumption, data on a more disaggregated level is not currently available.

vehicle excise duty, the VAT applied to petroleum and the air passenger duty, which applies to air travel within the European Economic Area (EEA), but at a lower rate with countries outside the EEA. The other less important sources of environmental tax revenue relate to the mining and quarrying industries, landfill and the aggregates levy.

Although it is assumed the effect of environmental taxes on pollution and energy consumption should be negative, it may not be significant due to exemptions to energy-intensive industries. A number of studies have suggested that to maintain 'international competitiveness', the effectiveness of these taxes has been reduced through offering exemptions to these industries. Ekins and Speck (1999) note that this is a feature of member states in the EU and has important implications for the effectiveness of these taxes and welfare costs for the economies concerned.

Ekins and Speck (1999) detail many examples of energy intensive industries, wholly or partially being exempted from the environmental taxes, including the Scandinavian countries. These exemptions can lead to the taxes being spread out on goods, which use little energy or for which demand is inelastic and therefore tend not to lead to any sizeable reduction in energy use or subsequent pollution. In addition, to restore competitiveness, pollution abatement subsidies are often used, however as Fredriksson (1997) has suggested, the interaction between the subsidy, tax rise and pollution, can in some circumstances even lead to a rise in pollution. The justification for these exemptions is not just economic, but also environmental, as if an industry in the EU becomes uncompetitive, it may switch production to a country outside the EU where environmental regulations and taxes are less stringent. Due to these concerns the EU approach to environmental policy has undergone a series of changes since

2001/2002, whereby the EU has stressed the need for co-ordination among the member states rather than trying to impose controls[4].

2.2 A dynamic panel approach to modelling pollution and energy consumption.

The above conventional approach assumes adjustment to the desired or target levels of pollution or energy consumption is rapid, however if we assume adjustment is only partial, we need to estimate an alternatively specified model, using a dynamic panel approach. The empirical model is then based on the partial equilibrium theory to account for any partial adjustment towards target levels of pollution. This may better reflect environmental policy in the EU more accurately, given that all member states have been allocated targets for their pollution levels under the Kyoto Protocol, including those countries which sought to join the EU during the late 1990s and early 2000s. Therefore in equation (1), the dependent variable can be interpreted as a desired or target level of pollution or energy consumption $(pcpoll_{it}^{*})$. The partial adjustment mechanism takes the following format:

$$pcpoll_{it} - pcpoll_{it-1} = \lambda(pcpoll_{it}{}^{*} - pcpoll_{it-1}) \tag{2}$$

This indicates that the change in the level of pollution ($pcpoll_{it}$) is proportional to the gap between its target level ($pcpoll^{*}{}_{it}$) and actual level[5]. This can be rearranged to form:

[4] In 2001 a report entitled: 'Simplifying and Improving the Environment' was first published, which has lead to a change in policy, from the EU being in charge of environmental policy to the individual member states being responsible. A discussion of EU environmental policy is beyond the scope of this study, but the European Commission (2005) among other reports provides a discussion of these issues.

$$pcpoll_{it} = (1-\lambda)pcpoll_{it-1} + \lambda pcpoll^*_{it} \qquad (3)$$

Where the term λ measures the speed of adjustment and is assumed to be positive, as the adjustment process should be both stable and non-fluctuating. The target level of pollution is assumed to be determined by the same explanatory variables as pollution in equation (1), then substituting it into (3) and rearranging produces the following estimating equation:

$$pcpoll_{it} = \alpha_0 + \alpha_1 pcpoll_{it-1} + \alpha_2 pcy_{it} + \alpha_3 pcy^2_{it} + \alpha_4 pck_{it} + \alpha_6 tax_{it} + u_{it} \quad (4)$$

Apart from accounting for the possible partial adjustment, there is a further reason for using an Arellano-Bover dynamic panel, which is to remove the individual effects in the panel as well as to take account of the potential endogeneity of the explanatory variables. Generalised Method of Moments (GMM) is used to estimate the model, using single lags of the transformed and non-transformed variables as instruments. The Arellano-Bover (1995) approach, used in this study involves using orthogonal deviations to remove the individual effects. Bond (2002) suggests the Arellano-Bover approach may have some advantages over other approaches to dynamic panel models, as it has better small-sample properties, and as long as the time series component is

[5] The dynamic panel approach has been used in other contexts for estimating a partial adjustment based model, such as Cheng and Kwan (2000), although they used the Arellano-Bond approach. In addition to incorporating partial adjustment, it can also remove the potential problems of endogeneity and autocorrelation. This can provide an alternative to differencing the data, which could have resulted in a loss of long-run information.

reasonably small, as in this case, the estimator does not require time stationarity to hold.

3. Data and Results

The data is all annual and runs from 1995 to 2006 and includes all the economies that are currently members of the EU[6] and for which there is data, including those that joined the EU recently such as the transition economies (The list of countries is included in Table 1). Norway is also included in the panel despite not being a member of the EU, because along with the other Scandinavian countries it has been in the vanguard of those countries implementing policies aimed at benefiting the environment. Although the data covers the era, when some countries were not direct members of the EU, they were preparing to join and trying to conform to the more environmentally friendly policies that the EU encouraged over the sample period.

The data is taken from the *Statistics Office of the European Communities* (*Eurostat)* and includes real GDP, capital formation, the total population and the environmental tax revenue relative to both GDP and total tax revenue data. The data on pollution is an index defined as the total greenhouse gas emissions (CO_2 equivalent). The

[6] The EU data is used due to the recent availability of its environmental tax data and the extensive literature on the implementation of environmental tax policy in the EU. In addition the definitions of both tax revenue and the pollution index are roughly common across the EU countries in the sample, ensuring the data shares the same features across the variables in the panel. However the data only starts in 1995 for many of the countries in the sample, limiting the dataset to just 300 observations. The data was taken from the *Economic and Social Data Services (ESDS)* website, which contains the *Eurostat* database.

consumption of energy is defined as ‘gross inland consumption’ in terms of thousands of tonnes of oil equivalent. Table 1 provides the summary tax statistics for each country, the tax revenue statistics suggest that most countries collect about 3% of GDP in environmental taxes, with the Scandinavian countries having the highest mean, whilst the transition countries have the lowest. With respect to total tax revenue collected, for most countries, the amounts collected are about 8%, with again the Scandinavian countries being particularly high[7]. However both Malta and Cyprus have the highest percentages, with 12% of tax revenue in Malta coming from environmental taxes, this may reflect the fact that they are new entrants to the EU and had to implement ETR prior to joining.

Table 2 contains the results using the measure of energy consumption and the related measure of pollution, as well as the two different measures of environmental tax revenue. Depending on the Hausman test, in which the null hypothesis is that random effects are consistent and efficient, the models are estimated using cross sectional fixed or random effects with Whites adjusted standard errors and covariances. In the first two models, the environmental tax relative to GDP and total taxes are negative and significant, suggesting as environmental taxes have risen, so air pollution within

[7] Dummy variables were included in the models to determine if different political groups of EU members have had different results. For instance an interaction dummy variable representing the Scandinavian countries interacting with the tax variables, who were the first and most enthusiastic members to implement environmental tax policy, were included in the dynamic panel to determine if they have had more success with controlling pollution than the other countries in the sample, but as it was insignificant it was removed. Similar results were obtained when interaction dummy variables for Euro member states with tax were included. This result is in accord with other studies that have included political determinants, such as Neumayer (2003).

the EU has, as expected fallen, particularly with environmental taxes relative to the total tax revenue, which is significant at the 1% level, indicating that environmental taxes need to be considered in relation to other taxes, as suggested by Goulder (1995). However there is no significant relationship between taxes and consumption of hydrocarbons, this suggests that much of the reduction in pollution is through cleaner vehicles and less polluting technologies rather than a reduction in energy consumption. The sensitivity of the relationship between environmental taxes and the dependent variables depends on the definition of the tax variable, being roughly double for the tax relative to GDP measure. Where a 1% rise in tax relative to GDP produces a 3% decline in pollution. There is little evidence that per capita income in both the linear and non-linear form has had much effect on pollution, although it does appear to affect energy consumption. The level of capital appears to have a positive effect on both pollution and energy consumption, but is only significant in the first model.

Table 3 includes the results from the Arellano-Bover dynamic panel approach, to account for any partial adjustment in the models, using lags of the transformed and non-transformed variables in the model as instruments, with Sargan's test accepting the null that the overidentifying restrictions are valid. These results are similar to the standard panel data models in Table 2 as they suggest environmental taxes only have a significant negative effect on pollution.

In the pollution model using environmental taxes relative to total taxes, capital has a significant negative effect as expected and in contrast to the non-dynamic specification, per capita income and per capita income squared are both negative and only the squared term significant. The significant negative effect on capital suggests that capital investment has facilitated less environmentally damaging production techniques which are more fuel efficient. The income terms suggests that pollution and energy consumption, with respect to wealth, tend to follow a non-linear pattern as suggested by Grossman and Kreuger (1995). However the energy consumption model with the dynamic panel, per capita income is negatively signed but significant in one model and positive in the other, emphasising the complicated nature of the relationship between income and pollution. The highly significant and positively signed lagged dependent variables in all four specifications, show that there is strong evidence of partial adjustment to the desired or target levels of pollution, with about 40% of adjustment occurring after one time period in the pollution models and about 60% in the energy models, again emphasising the need to treat the dependent variable as a target in conjunction with a partial adjustment mechanism.

4. Conclusion

This study suggests that the recent introduction of environmental taxes in the EU has had a significantly negative effect on pollution, but limited effect on the use of natural resources. This suggests that the myriad exemptions for energy-intensive sectors of the economy detailed in the literature have had only a limited effect on the efficacy of this policy. These results also provide support for those studies suggesting that the consequences of environmental taxes are dependent on the structure of other tax levels, as measuring environmental taxes relative to total taxes has the most significant effect. However there is mixed evidence on levels of income having any effect on pollution and energy consumption, as also found in other studies.

There is evidence to support an alternative approach to modelling pollution and energy consumption, with these variables being treated as target or desired levels rather than the actual level, as is the case in the EU and increasingly in most other countries. In this case a partial adjustment mechanism in conjunction with a dynamic panel approach could offer an alternative to the conventional methodology used in the pollution literature and thereby produce a better specified overall model. The results indicate the presence of inertia, with between 40% and 60% of adjustment to the target or desired levels of pollution being accomplished annually. These results appear to suggest that taxes are predominantly determining the target level of pollution.

The policy implications of these results are that the current use of environmental taxes to reduce the EU's present levels of pollution appear to be having some effect, although the relationship with other taxes needs to be considered. The lack of a significant effect on energy consumption, suggests environmental taxes are not reducing consumption, implying pollution is being reduced through the use of cleaner technologies. However future research will need to incorporate the effects of the use of environmental subsidies and renewable energy sources as they extend across the EU and as more data becomes available. In addition extended datasets with non-EU countries also need to be assessed, again as comparable tax data becomes available in the future.

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Table 1 Summary Statistics regarding tax revenue (%)

	% of GDP		% of total tax	
Country	**mean**	**variance**	**mean**	**variance**
Austria	2.44	0.05	5.66	0.25
Belgium	2.34	0.01	5.20	0.06
Czech Republic	2.57	0.02	7.30	0.07
Cyprus	3.02	0.26	9.92	1.02
Denmark	5.23	0.17	10.66	0.64
Estonia	1.77	0.20	5.50	2.72
Finland	3.13	0.02	6.93	0.12
France	2.56	0.04	5.85	0.20
Germany	2.38	0.03	5.93	0.27
Greece	2.53	0.19	8.01	2.69
Hungary	2.99	0.06	7.72	0.30
Ireland	2.69	0.10	8.61	0.52
Italy	3.16	0.09	7.59	0.50
Latvia	2.29	0.22	7.59	2.74
Lithuania	1.80	0.12	6.12	1.38
Luxembourg	2.87	0.01	7.51	0.14
Malta	3.48	0.10	11.94	3.55
Netherlands	3.82	0.02	9.79	0.17
Norway	2.44	0.53	5.70	2.76
Poland	2.21	0.12	6.55	1.68
Portugal	3.19	0.06	9.41	0.97
Spain	2.12	0.02	6.22	0.31
Sweden	2.85	0.01	5.72	0.05
United Kingdom	2.83	0.06	7.82	0.51

Table 2 Pollution and energy consumption models.

	Pollution	Pollution	Energy Consumption	Energy Consumption
Constant	-11.249*	-11.445*	-2.094*	-2.545*
	(22.332)	(31.757)	(2.968)	(3.541)
Pcy	-0.004	-0.119	1.653*	1.512*
	(0.033)	(0.757)	(5.894)	(5.037)
Pcy^2	0.001	-0.013	0.134*	0.128*
	(0.046)	(0.799)	(4.577)	(3.832)
Pck	0.034*	0.026	-0.081	0.051
	(2.011)	(1.514)	(1.460)	(0.664)
Taxy	-2.96*		0.064	
	(2.466)		(0.351)	
Taxt		-1.744*		0.075
		(3.161)		(0.115)
Adjusted R^2	0.04	0.99	0.23	0.98
Effects	random	fixed	random	fixed
Hausman	2.780	12.460	8.344	14.599
Observations	300	300	300	300

Notes: T-statistics in parentheses, Variable names as in equation (1), A * (**) indicates significance at the 5% (10%) level of significance. All regression include fixed cross sectional effects and White cross section standard errors and covariances.

Table 3 Dynamic panel estimation of pollution and energy consumption models

	Pollution	Pollution	Energy Consumption	Energy Consumption
Poll/En (-1)	0.664*	0.610*	0.431*	0.402*
	(41.064)	(56.931)	(38.392)	(31.106)
Pcy	0.051	-0.081**	-0.575*	0.673*
	(0.492)	(1.768)	(2.973)	(2.431)
Pcy^2	0.002	-0.016*	0.052*	0.060
	(0.241)	(5.141)	(2.500)	(0.182)
Ky	-0.003	-0.052*	-0.007	-0.007
	(0.099)	(2.605)	(0.140)	(0.182)
Taxy	-1.627*		0.033	
	(4.665)		(0.016)	
Taxt		-0.735*		0.003
		(8.437)		(0.647)
J-statistic	20.626	23.851	19.425	19.747
OIR(Sargan)	0.419	0.249	0.494	0.474
Observations	250	250	250	250

Notes: Variables are as in Equation (4). OIR is the Sargan test for overidentifying restrictions, with the p-value included. All models estimated using GMM and orthogonal deviations, with White period instrument weighting matrix and standard errors and covariance matrix. The instruments include the second lag of the dependent variable and first lags of the explanatory variables in both the transformed and untransformed form.